

Yield, Chemical Composition, and Eating Quality of Heirloom Tomatoes Grown in the Subtropical Climate of Florida

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Florida small farm growers and producers are interested in strategies that can differentiate their operation and products from the competition and heirloom tomato (*Solanum lycopersicum* L.) varieties have potential for adoption by small farm producers in Florida. Marketable yield, chemical compositions [vitamin C, pH, total soluble solid (TSS), titratable acidity (TTA)], and eating quality (semi-trained panelist, $n = 38$) of six tomato cultivars ('Arkansas Traveler', 'Brown Berry', 'Cream Sausage', 'Jaune Flamme', 'Nyagous', 'Mortgage Lifter') of field and shade-grown heirloom tomatoes were evaluated during Spring 2007 at the North Florida Research and Education Center–Suwannee Valley (NFREC-SV), in Live Oak, FL. Marketable yield of cultivars ranged from 0.9 to 4.57 kg/plant. The tomato cultivar with the highest vitamin C content was 'Brown Berry' (26.18 mg/100g) and the lowest vitamin C content was in 'Nyagous' (13.40 mg/100g). The sensory evaluation was conducted only on varieties with high marketable yield from Live Oak ('Brown Berry', 'Cream Sausage', and 'Jaune Flamme'). Age and gender of the taste panel did not affect the rating score of the sample ($P > 0.05$) but samples were significantly different ($P < 0.0008$). There was no specific trend that indicated a flavor preference for shade-grown tomato compared to field-grown tomato. A similar trial was completed during Fall 2007 at NFREC-SV and Winter 2007–08 at the Tropical Research and Education Center in Homestead, FL. Those studies evaluated yield and fruit quality of six cultivars considered "red slicers" produced hydroponically in open shade houses. Several heirloom cultivars tested in this trial were suitable for direct market, but none would be suitable for large-scale commercial production.

Heirloom tomatoes are open-pollinated tomato cultivars that breed true to type, have been in production for at least 50 years, and are valued over the generations (Watson, 1996). The wide variety of colors, shapes, sizes, and flavors makes them very appealing to consumers who desire flavor more than keeping quality. Heirloom tomato cultivars are channeled primarily through direct markets due to their inability to withstand the rigors of picking, packing, and shipping compared to the cultivars used in the commercial tomato industry. The increasing demand for locally produced fruits and vegetables has generated renewed interest in heirloom tomatoes from producers who desire to differentiate their operation and products from the competition. Some consumers perceive heirloom tomatoes as symbol of their elite

status and will pay \$7 per pound for fruit at specialty markets, but these cultivars are also available to limited resource consumers who purchase fruit at local markets through government-assisted nutrition programs (Jordan, 2007).

Fresh market tomato accounts for nearly 39,000 acres in Florida and generated a farm gate value of 403 million dollars during the 2006–07 production season (USDA NASS, 2007). There are several production constraints to large-scale commercial adoption of heirloom tomatoes. Heirloom tomatoes have a tendency to crack at the stem end and create openings in the epidermis. The cracks surrounding the stem scar provide an entry for plant pathogens that in turn reduce quality and shelf life. Further, enteric pathogenic bacteria have been documented to enter cracks and reside in fruit for several weeks and thus pose a risk to food safety (Orozco et al., 2007). Heirloom cultivars tend to lack resistance to nematodes, insects and disease, and therefore require

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more management, labor, and inputs. Physiological diseases such as zippering, caused when anthers attach to the ovary wall of newly forming fruit and cat-facing, caused by a combination of abiotic factors including cool weather, pruning, and high N, reduce aesthetic quality and market grade of affected fruit. Many cultivars are indeterminate and require tall stakes for support or frequent pruning to limit vertical growth. Leaf cover is highly variable among cultivars, and when coverage is poor, high light intensity can lead to sunscald. Finally, their variable fruit shape and soft flesh interfere with a consistent pack out.

Protected culture of heirloom tomatoes is one strategy used to reduce the negative effects of the inherent genetic characteristics of heirloom cultivars as well as mitigate the effects of Florida's hot and humid climate on fruit quality and yield. Vegetable production using soilless culture under open shade structures is one production strategy that can reduce the negative effects of soil-borne disease, regulate water application, and reduce the negative effects of high heat and light intensity on fruit set and quality. A preliminary trial in Live Oak, FL examined bell pepper (*Capsicum annuum* L.) grown in soilless culture in 5-kg pots under an open shade structure in Live Oak, FL produced more than 3460 boxes/acre of US Fancy fruit during a 5-month period from June to November (Hochmuth et al., 2007). Based on those observations, we hypothesized that heirloom tomato may be a suitable crop for an open shade hydroponic production system. The overall goal of the two experiments presented here is to evaluate the fruit quality, yield and consumer taste preference of heirloom tomato cultivars produced in the field and open-shade structures in north central Florida and southern Florida, and to identify cultivars with potential for commercial adoption. In Spring 2007, the objectives were to determine if heirloom cultivars produced in an open shade house would produce higher marketable yields than the same cultivars grown in the field using standard grower practices, and to compare consumer taste preference and chemical composition of six heirloom cultivars. Additionally, four new cultivars were tested in Fall 2007 and Winter 2007–08 to identify the cultivar with the most marketable yield.

Materials and Methods

Two experiments were performed during the 2007 season. In Spring 2007, six heirloom tomato cultivars were examined in the field compared to an open shade house structure at North Florida Research and Education Center (NFREC)–Suwannee Valley in Live Oak, FL. In Fall 2007, two cultivars from the spring trial, plus four new cultivars were selected for further study under an

open shade house. Cultivars used in all three locations are summarized in Table 1. The Fall 2007 experiment was replicated at Tropical Research and Education Center (TREC) in Homestead, FL in Winter 2007–08.

SPRING 2007. This was an observational study in preparation for the fall experiments, and was not replicated. Six heirloom tomato cultivars including: 'Arkansas Traveler', 'Brown Berry', 'Cream Sausage', 'Jaune Flamme', 'Nyagous', and 'Mortgage Lifter' were produced in the field and hydroponically in perlite bags under shade in Live Oak, FL. Tomato seed was planted in 128 cell plastic trays filled with a peat-perlite-vermiculite soil-less media (Superfine germinating mix, Fafard Industries) and irrigated daily (2x/day at 2–3 min each time) in polyethylene greenhouses with fan and pad ventilation until transplanting. Plants were supplied with a nutrient solution (50 ppm N) after true leaves appear, increasing to 80 ppm N near transplanting time). Tomatoes were transplanted in the field and in the shade house on 22 Mar. 2007.

In the field, at total of 48 tomato plants were established (six cultivars × eight plants per cultivar). Transplants were spaced 18 inch apart in the row on 24-inch beds with high-density polyethylene mulch. Plants were provided nutrient solution described by Hochmuth and Hochmuth (2001) at 120 ppm N.

In the shade house, transplants were placed in 42 inch × 8 inch × 6 inch perlite-filled bags under open shade structures approximately 5 weeks after seeding. Each perlite bag contained two tomato plants and spacing was 21 inches apart in the row. A total of four perlite bags were used per cultivar. The shade house in Live Oak was a 40 ft × 40 ft commercial modular shade house (Atlas, Alapaha, GA). The structure was made from galvanized pipe and covered with a black 50% polypropylene shade cloth. Additional shade cloth on the east and south walls was used during periods of high heat. Nutrient management in Live Oak consisted of individual nutrients mixed into solution as described by Hochmuth and Hochmuth (2001).

Fruit from all cultivars were harvested from both the field and the shade house from 30 May until 2 July for a total of six harvests. Following the 18 June harvest, flavor and eating quality were evaluated through results from two independent consumer panels, one at each location. Ten semi-trained panelists of mixed gender and ages (ranged from 18 to 70 years old) conducted a sensory evaluation on the four cultivars with the highest yield and quality. Three cultivars, 'Mortgage Lifter', 'Arkansas Traveler', and 'Nyagous', were omitted from the trial due to the extensive cracking observed on the shoulders of the fruit. Fruit with market grades similar to USDA Fancy and No.1 were selected for evaluation.

Table 1. Cultivar descriptions and seed sources used in the heirloom tomato cultivar experiments in Live Oak in Spring 2007 (S), Live Oak in Fall 2007 (F), and Homestead in Winter 2007–08 (W).

Cultivar	Season	Type	Characteristics	Seed source
Arkansas Traveler	S, F, W	Slicer	Medium, pink	Baker Creek Heirloom Seed Co., Mansfield MO
Black Krim	F, W	Slicer	Medium, purple	Gary Ibsen's TomatoFest, Carmel, CA
Brandywine	F, W	Slicer	Large, red	Gary Ibsen's TomatoFest, Carmel, CA
Brown Berry	S	Cherry	Red, acidic	Seed Savers Exchange, Decorah, IA
Carbon	F, W	Slicer	Medium, purple	Tomato Growers Supply Co., Ft. Myers, FL
Cream Sausage	S	Roma	Yellow	Seed Savers Exchange, Decorah, IA
Eva Purple Ball	F, W	Slicer	Medium, purple	Gary Ibsen's TomatoFest, Carmel, CA
Jaune Flamme	S	Slicer	Medium, orange, acidic	Seed Savers Exchange, Decorah, IA
Mortgage Lifter	S, F, W	Slicer	Large, red	Baker Creek Heirloom Seed Co., Mansfield MO
Nyagous	S	Slicer	Medium, purple	Baker Creek Heirloom Seed Co., Mansfield MO

FALL 2007 AND WINTER 2007–08. Following initial screenings of 12 cultivars over several seasons, six were selected for this trial based on highest fruit quality and yield. Due to the consumer demand for large red slicing tomatoes in direct markets, all six cultivars selected were medium to large slicing tomatoes. The cultivars included two from the Spring 2007 experiment: ‘Arkansas Traveler’ and ‘Mortgage Lifter’, plus four additional cultivars: ‘Black Krim’, ‘Brandywine’, ‘Carbon’, and ‘Eva Purple Ball’. Cultivars were arranged in a randomized complete-block design with four replications in Live Oak (six cultivars × four plants per cultivar × four replications = 96 plants total) and four replications in Homestead (six cultivars × two plants per cultivar × four replications = 48 plants total). In Live Oak, plants were placed in the same shade house as described for the Spring 2007 experiment. The shade house in Homestead was a 20-ft-long × 20-ft-wide commercial modular shade house (Gothic Arch Greenhouses, Inc., Mobile, AL) with a floor of landscape fabric over gravel. A black 60% polypropylene shade cloth covered the ceiling and the south side to reduce heat, with remaining sides open to improve air flow.

Water was delivered by drip irrigation and emitter stakes, and the same lines were used to deliver a blended hydroponic nutrient solution. Nutrient management in Live Oak was the same as that described for the Spring 2007 experiment. Nutrient management in Homestead consisted of a commercially available blended fertilizer containing 8N–6.6P–29.9K, plus micronutrients, (VertiGrow, Summerfield, FL) supplemented by calcium nitrate [Ca(NO₃)₂] and Epsom salt (MgSO₄·7H₂O). Although nutrient sources differed between locations, nutrient concentration and delivery were similar throughout the season. In both locations, leachate was monitored throughout the season to ensure minimal loss of nutrients.

Plants were scouted weekly for insects and disease and were treated according to UF-IFAS recommendations for tomatoes (Gillett et al., 2006). Fruit from each plant was harvested through-

out the season at first red color, and were graded, counted and weighed. Due to the variety of fruit shapes and sizes among heirloom cultivars, we modified the USDA grading standards for tomatoes to accommodate for the variation in shapes and sizes of the heirloom cultivars produced. The modified grading standards and characteristics of heirloom cultivars used in these experiments are summarized in Table 2.

Results and Discussion

SPRING 2007. The heirloom cultivars tested in this experiment were very different from each other in terms of size, appearance, fruit quality and yield. The cultivars ‘Brown Berry’ and ‘Cream Sausage’ were high-yielding cultivars in both the shade house and in the field compared to the remaining cultivars (Table 3). The total marketable fruit weight of ‘Brown Berry’ was 4.3 kg/plant in the shade house and 3.75 kg/plant in the field, while total marketable fruit weight of ‘Cream Sausage’ was 4.57 and 4.0 kg/plant in the shade house and in the field; respectively (Table 3).

Vitamin C, pH, TSS and TTA were different among cultivars (Table 4). ‘Brown Berry’ (26.18 mg/100g) yielded the highest vitamin C while ‘Nyagous’ yielded the lowest vitamin C (13.40 mg/100g) content. While the vitamin C content and pH of field produced tomato appeared higher than the shaded production, statistical analyses did not yield significant differences ($P = 0.0876$).

The sensory evaluation was conducted only on varieties with high marketable yield from Live Oak (‘Brown Berry’, ‘Cream Sausage’, and ‘Jaune Flamme’). Age and gender of the panelists did not significantly affect rating score of the sample ($P > 0.05$) while difference among the samples were significantly different ($P < 0.0008$) (data not shown). Of the three cultivars subject to sensory evaluation, ‘Brown Berry’ produced in the field scored higher for overall taste preference than ‘Jaune Flamme’ produced in the field or shade, and ‘Cream Sausage’ produced in the shade

Table 2. Tomato quality grading standards used for the heirloom tomato cultivar experiment in Live Oak in Spring and Fall 2007 and in Homestead in Winter 2007–08.

Grading characteristic	Criteria for grade classes			
	Fancy	No. 1	No. 2 ^a	Cull
Damage caused by insects, diseases, and viruses	None allowed	None allowed	Minor damage that does not pose a risk to quality.	Allowed
Physiological disorders	None allowed	None allowed	None allowed	Allowed
Cracking	None allowed	Yes. Minor crack length and density relative to fruit size; superficial depth only; must be healed; on shoulder only.	Yes. Minor, but higher density and longer length than for No. 1. Cracks must be shallow and healed.	Allowed
Shape ^b	Exceptional shape; symmetric, absence of deep grooves on the shoulder, absence of exaggerated tips.	Typical for cultivar. Symmetric.	Typical for cultivar, but with some asymmetry or exaggerated shoulders or tips.	Asymmetrical, and not typical for cultivar.
Size ^b	Larger than typical for cultivar.	Typical for cultivar.	Smaller than typical for cultivar.	Smaller than typical for cultivar.
Color	Consistent with cultivar.	Consistent with cultivar.	Subtle variation allowed.	Different than cultivar standard.

^aThe No. 2 market grade was not used for the Spring 2007 study. Rather, these fruit were classified as Culls.

^bTypical fruit size and shape were based on images and descriptions from seed catalogs.

Table 3. Means of tomato fruit yield per plant² by modified USDA market grade from six heirloom cultivars grown in the field and in an open shade house at NFREC–Suwannee valley in Live Oak, FL in Spring 2007.

Cultivar	Fruit grade							
	Fancy		No. 1		Total marketable		Culls	
	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)
<i>Field production</i>								
Arkansas Traveler	5.5	0.90	16.0	1.92	21.3	2.83	13.1	1.30
Brown Berry	183.5	2.56	120.8	1.20	304.3	3.75	53.5	0.47
Cream Sausage	37.1	2.52	27.9	1.49	65.0	4.00	24.3	0.97
Jaune Flamme	15.6	1.06	40.0	2.15	55.6	3.21	39.0	2.13
Mortgage Lifter	0.5	0.15	3.4	0.75	3.9	0.91	13.0	2.74
Nyagous	4.3	0.60	6.1	0.53	10.4	1.13	54.1	4.07
<i>Shade house production</i>								
Arkansas Traveler	9.4	1.35	18.4	2.17	27.8	3.52	13.5	1.02
Brown Berry	268.9	3.08	166.9	1.22	435.8	4.30	91.5	0.94
Cream Sausage	37.6	2.57	40.6	2.00	78.3	4.57	24.1	0.87
Jaune Flamme	31.3	1.67	36.6	1.51	67.9	3.18	45.4	1.70
Mortgage Lifter	8.8	2.82	4.5	1.14	13.3	3.96	6.6	1.76
Nyagous	9.0	1.02	16.1	1.19	25.1	2.22	49.3	3.72

²Means of eight plants each in the shade house and in the field for each cultivar.

Table 4. Selected chemical composition of heirloom cultivars produced in Spring 2007 at Live Oak, FL.

Cultivar	Chemical composition			
	Vitamin C (mg/100g)	pH	TSS ² (°Brix)	TTA ³ (% citric acid)
Arkansas Traveler	19.77bc ^x	4.54 b	4.81 cd	0.34 bc
Brown Berry	26.18 a	4.32 c	5.97 a	0.44 b
Cream Sausage	14.66 cd	4.22 d	4.6 d	0.44 b
Jaune Flamme	17.66 cd	4.05 d	4.8 cd	0.59 a
Nyagous	13.40 d	4.7 a	5.53 b	0.26 c
Mortgage Lifter	24.01 ab	4.16 d	5.04 c	0.58 a

²TSS = Total soluble solids as percent citric acid.

³TTA = Titratable acidity expressed in degrees Brix.

^xMean separation (in column) by Duncan's multiple range test ($\alpha = 0.05$).

scored higher for overall taste preference than 'Jaune Flamme' produced in the shade (Table 5). There was no specific trend that indicated a flavor preference for shade-grown tomato.

FALL 2007 AND WINTER 2007–08. Yields and quality of tomato fruit were different among cultivars in both Live Oak and Homestead. In Live Oak, the only cultivar yield differences were for unmarketable fruit (culls) (Table 6). Culls were highest

for 'Carbon' (2.05 kg/plant) and lowest for 'Mortgage Lifter' (3.3 kg/plant). The total marketable yields were similar among cultivars 'Carbon' (1.04 kg/plant) and 'Brandywine' (1.59 kg/plant) (Table 6). In Homestead (Table 7), total marketable yield among cultivars was more variable than Live Oak. Total marketable fruit weight was highest for 'Eva Purple Ball' (3.91 kg/plant) and similar to 'Arkansas Traveler' (3.68 kg/plant) and 'Mortgage Lifter' (3.22 kg/plant). Total marketable fruit weight was lowest for 'Brandywine' (1.34 kg/plant) which was similar to 'Black Krim' (2.10 kg/plant) and 'Carbon' (2.06 kg/plant). It is likely that the plants in Live Oak did not reach their full yield potential due to a lack of fruit set early in the season associated with higher than normal air temperatures in the fall. Stressed plants were observed in Homestead following a period of high winds and cool temperatures in early Jan. 2008. Although the shade house does afford some advantages over field production, it does not fully protect plants from unfavorable weather.

Based on the marketable yield, chemical composition, and eating quality, none of the varieties tested was exceptional. Several heirloom cultivars tested in this trial were suitable for direct market, but none would be suitable for large-scale commercial production.

Table 5. Sensory evaluation of 'Brown Berry', 'Cream Sausage', and 'Jaune Flamme' heirloom cultivars produced in Spring 2007 at Live Oak, FL using semi-trained panelists.

Cultivar	Treatments	Sensory quality			
		Tomato flavor	Sweetness	Acidity (sourness)	Overall preference
Brown Berry	Field	6.2 a ²	4.2 a	3.7 bc	5.2 a
	Shade	5.9 ab	3.6 ab	4.6 ab	4.6 abc
Cream Sausage	Field	5.1 bcd	2.8 b	3.5 c	4.4 abc
	Shade	4.4 d	3.1 b	3.4 c	4.89 ab
Jaune Flamme	Field	4.8 cd	3.05 b	5.2 a	4.02 bc
	Shade	5.7 abc	3.1 b	4.05 bc	3.9 c

²Mean separation (in column) by Duncan's multiple range test ($\alpha = 0.05$).

Table 6. Tomato fruit yield per plant by modified USDA market grade from six heirloom cultivars grown in an open shade house at NFREC-Suwannee valley in Live Oak, FL in Fall 2007.

Cultivar	Fruit grade									
	Fancy		No. 1		No. 2		Total marketable		Culls	
	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)
Arkansas Traveler	1.7	0.26	3.8	0.48	5.2	0.52	10.7	1.26	8.5 ab ^z	1.05 bc
Black Krim	1.0	0.23	2.8	0.62	3.8	0.56	7.5	1.39	8.0 ab	1.60 ab
Brandywine	1.8	0.53	2.8	0.67	2.6	0.39	7.3	1.59	4.3 bc	0.86 bc
Carbon	0.7	0.16	2.2	0.44	3.2	0.44	6.1	1.04	11.6 a	2.05 a
Eva Purple Ball	1.8	0.27	2.6	0.30	7.5	0.65	11.8	1.21	4.3 bc	0.39 c
Mortgage Lifter	1.6	0.46	2.6	0.68	3.1	0.43	7.3	1.57	3.3 c	0.69 c
Significance	NS	NS	NS	NS	NS	NS	NS	NS	0.006	0.003

^zMean separation (in column) by Duncan's multiple range test ($\alpha = 0.05$). NS = Nonsignificant.

Table 7. Means of yield and modified USDA market grade of tomato fruit per plant from six heirloom cultivars grown in an open shade house at TREC in Homestead, FL in Winter 2007–08.

Cultivar	Fruit grade									
	Fancy		No. 1		No. 2		Total marketable		Culls	
	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)	No. of fruit	Total wt (kg)
Arkansas Traveler	3.7 bc ^z	0.86 bc	7.2	1.20	15.8 b	1.62 b	26.7 b	3.68 a	2.7 bc	0.45 abc
Black Krim	5.3 ab	1.27 ab	2.3	0.39	3.8 b	0.44 c	11.3 c	2.10 bc	3.6 abc	0.77 ab
Brandywine	1.5 cd	0.45 cd	3.9	0.66	2.1 b	0.23 c	7.5 c	1.34 c	6.0 ab	1.00 a
Carbon	4.6 b	1.17 ab	3.9	0.57	3.1 b	0.32 c	11.6 c	2.06 bc	6.9 a	1.10 a
Eva Purple Ball	0.0 d	0.00 d	2.8	0.48	44.6 a	3.44 a	47.4 a	3.91 a	1.3 c	0.06 c
Mortgage Lifter	7.1 a	1.69 a	4.8	0.78	7.1 b	0.75 bc	19.0 bc	3.22 ab	1.1 c	0.20 bc
Significance	0.0001	0.0002	NS	NS	0.0001	0.0001	0.0001	0.0085	0.0187	0.0024

^zMean separation (in column) by Duncan's multiple range test ($\alpha = 0.05$). NS = Nonsignificant.

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